International Journal of Advances in Management Science, 2012, 1: 7-12
Published Online July 2012

http://www.ij-ams.org

Arable Land Area Forecast Based on GM (1, 1) Model: A Case of Sichuan Province, China

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(Abstract) To explore the arable land area change in the next years so that the corresponding measures should be taken, this paper introduces GM (1, 1) model and the data for the statistics is used to forecast the arable land area in Sichuan province. The result shows that the arable land area should be decreased from 394.23 ten thousand hm^2 to 386.64 ten thousand hm^2, moreover, this paper finds that the GM (1, 1) model has a higher forecasting accuracy than regression model. On that base, the policy implication of arable land protection such as changing protection approach, developing all level scale cities in different region, using intensively urban land is put forward in this study.

Keywords: Arable Land; Land Management; GM (1, 1) Model; Sichuan Province.

1. INTRODUCTION

Land, especially arable land is a fundamental factor for economic development. As the famous economist William Petty once said nature is the mother of wealth and the father of labor. China is an important economy body with a huge population and relatively less arable land resource. Firstly, China's GDP reached 592.67 billion US dollars (current price) and ranked the world's second (World Bank) in 2010. Secondly, China's population amounted to 13.38 billion while the average arable land area was only 0.08 hm^2 in 2010, which is far less than Canada, Austria, America and Russia. They are 1.34 hm^2, 2.15 hm^2, 0.54 hm^2 and 0.86 hm^2 respectively. On the other hand, China lags behind in agricultural technology. For instance, the grains productivity in China in 2010 is 5521 kg/hm^2 while America is 6988 kg/hm^2. Simultaneity, China has a relatively lower urbanization level with fifty per cent while the average level is up to 75%. To some extent, to improve urbanization level means decreasing in arable land area. All those factors show that it is essential to maintain arable land at a high level. However, the fact is China's arable area has kept decreasing over the last decades. The Statistical data from Ministry of Land and Resources in China indicate that the arable land area reduced from 1.284 billion hm^2 to 1.217 billion hm^2 over the period of 2000-2008. This not only results in food risk but also brings about ecology risk. So, all level governments in China pay high importance on arable land protection. Obviously, the key scientific problem is how much arable land area we should maintain during we carry out the relative arable protection policies. To make an attempt to realize this goal, this paper forecast arable land area in Sichuan province base on the model of GM (1, 1).

This paper unfolds as follows: the second part reviews the relative literature so as to explain why this paper uses this model. The third part is methodology, which gives the GM (1, 1) model and shows why this paper choose Sichuan province as an example. The fourth part presents the main findings and results of this study. And the last part put forwards conclusion and policy implication.

2. LITERATURE REVIEW

There is an increasing interesting in forecasting arable land area in China in the context of the importance of arable land protection. Although there has been lots of research concentrated on the topic of forecasting arable land area, all of them falls into the following two catalogs: (1) research based on econometrics model; These research use time series model such as auto-regressive and moving average (ARMA) Model or causality model to establish an econometrics model. Not only time series model but also causality model is under the assumption of cause-effect relation between dependent variables and independent variables. Basically, the regression analysis technologies are usually employed to acquire the parameter. For example, He et al. (2006) established ARMA model raking Qingdao city as an example and forecasted the requirement of arable land area over the period of 2005-2015. The results showed that the arable land area in Qingdao city in 2005 would be 41.72 ten thousand hm^2, 38.37 ten thousand in 2010 and 35.44 ten thousand hm^2 in 20151. Xia et al. (1999) regarded urban population as dependent variables based on taking Hunan province as an example and established a regression model in order to forecast the arable land area .it demonstrated that the total population in Hunan province in 2010 would reach seventy million at the same time the arable land area would reduced to sixty-five thousand hm^2. Zhou (2012) proposed a cultivated land area forecast method based on least squares support vector machines while they took Changde City, Hunan province

as an example to calculate the arable land area. The results shows that this model can improve the predication accuracy of cultivated land area compare with other method[2]; (2) other than econometrics model, the other research concentrated on some forecasting technologies such as grey forecast model, Jia (2002) employed GM (1, 1) model to forecast the cultivated land resources area using the statistic data of cultivated land resources in Wuhu city, Anhui province. The result demonstrated that there are 8.96 ten thousand cultivated land resources area in Wuhu city in 2000, 8.76 ten thousand in 2005 and 8.57 ten thousand in 2010[3]. Zhang et al. (2009) developed a prediction method of cultivated land change based on least squares support vector machines by studying the inherent tendency toward land change and simulating the trajectories of changes in Wuxi city's land use. The results showed that the arable land area was 18.48 ten thousand in 1990, 17.75 ten thousand in 1995 and 17.55 ten thousand in 2000. Moreover, compared with other models, this model had higher prediction accuracy[4]. Liu yaolin (2004) analyzed the advantages and disadvantages of grey GM (1, 1) prediction and Markov prediction model. On that base, they presented a new method called grey Markov model using Hubei province arable land area and concluded that the land area change rate over the period of 1998-2000 is 3.27% in Hubei province; 2000-2005 is 4.45 and 2005-2010 is 0.53. By this change rate and the actual arable land area in 1998, they forecasted out that the arable land area in Hubei province in 2000 would be 3.30 million hm[25]. Sunyan et al. (2008) introduced a dynamic model and calculated the total area of farmland in China seeing that China's FARMLAND area was decreasing at a high speed over the period of 2000-2008. They reached a conclusion that effected by constructional land use, ecologic comeback, agriculture industrial structure adjustment catastrophic and so on; the farmland area would be reduced into 1.21 billion hm^2 by the year of 2010[6].

In all, many methods or forecast technology were produced to make out how much arable land area would be maintain in the future in all levels, including a county, a city, a province and a country. These studies laid a good foundation for this paper. However, on one hand Sichuan province is one of main grains production locations so that it much more important to maintain its arable land area at a high level; on the other hand compared with other models GM (1, 1) doesn't need too much assume while it has much higher accuracy. So, this paper introduces GM (1, 1) model taking Sichuan province as an example.

3. METHODOLOGY AND DATA COLLECTING

3.1 Model

Grey systems theory is originated by Julong Deng, a well-known mathematician in former Wuhan Polytechnic University, present Huazhong University of Science & Technology in the early 80s in the 20th century. Then grey model is based on the grey systems theory and GM (1, 1) is one of the numerous grey models which is widely used to forcast in the field of nature, geography, society and economy. Followed by Wang (2012)[7], Lu (2010)[8] and Deng (1989)[9], this paper introduces the GM (1, 1) model as follows:

GIVEN The first-order differential equation is:

$$\frac{dX^{(1)}}{dk} + aX^{(1)} = u \tag{1}$$

Where k denotes the system independent variable; a represents the development coefficient, u is the grey control variable, and a and u are the model particular parameters. Suppose that the original series $X^{(0)}$:

$$X^{(0)} = \left\{X^{(0)}(1), X^{(0)}(2), \cdots, X^{(0)}(n)\right\}$$

In the model construction of grey system, the original series $X^{(0)}$ is first made the first-order accumulated generating operation (AGO) to provide an intermedium message for model construction and weaken the randomness of the original series. $X^{(1)}$ is defined herein as the first-order AGO series of $X^{(0)}$, that is

$$X^{(1)} = \left\{X^{(1)}(1), X^{(1)}(2), \cdots, X^{(1)}(n)\right\} \tag{2}$$

Where

$$X^{(1)}(k) = \sum_{i=1}^{k} X^{(0)}(i), \quad k = 1,2,\cdots,n$$

The coefficient $\hat{a}$ is obtained from (1), (2) and the least square method:

$$\hat{a} = (a,u)^T = (B^T B)^{-1} B^T Y_n \tag{3}$$

Where the accumulated matrix B is:

$$B = \begin{bmatrix} -\frac{1}{2}(X^{(1)}(2) + X^{(1)}(1)) & 1 \\ -\frac{1}{2}(X^{(1)}(3) + X^{(1)}(2)) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}(X^{(1)}(n) + X^{(1)}(n-1)) & 1 \end{bmatrix}$$

And the constant term vector Y_n is:

$$Y_n = \left[X^{(0)}(2), X^{(0)}(3), \cdots, X^{(0)}(n)\right]^T$$

The coefficient $\hat{a}$ is substituted into the differential equation to solve (1) and obtain the approximate relation:

$$\hat{X}^{(1)}(k+1) = (X^{(0)}(1) - \frac{u}{a})e^{-ak} + \frac{u}{a} \qquad (4)$$

Where $\hat{X}^{(0)}(1) = X^{(0)}(1)$, (4) is made the first-order inversed-accumulated generating operation (IAGO) to obtain the restored series value $\hat{X}^{(0)}(k)$:

$$\hat{X}^{(0)}(k) = \left[X^{(0)}(1) - \frac{u}{a} \right] e^{-a(k-1)}(1-e^{a})$$

We let $k = 1,2,\cdots,n$, and restore the series $\hat{X}^{(0)}$:

$$\hat{X}^{(0)} = (\hat{X}^{(0)}(1), \hat{X}^{(0)}(2), \cdots, \hat{X}^{(0)}(n)) \qquad (5)$$

Precision checking is further conducted through the generation and model construction mentioned above to realize the error $\delta(k)$ between the predicted and actual values. This study uses the residue checking to make a residue comparison based on the actual and predicted values, using the following formula:

$$\delta(k) = \left| \frac{X^{(0)}(k) - \hat{X}^{(0)}(k)}{X^{(0)}(k)} \right| \times 100\%, \ k = 2,3,\cdots,n \qquad (6)$$

The precision index is $1-\delta(k)$, and an average precision exceeding 90% indicates excellent model prediction efficiency.

So, use the above model and by data collecting, the arable land area can be forecasted out.

3.2 Data Collecting

This paper choose Sichuan province as a sample to forecast its arable land area not only because Sichuan is a traditional grains production region, which means arable land area is essential for agriculture industry but also there is a sharp conflict between land and people with the development of soc-economic. Over the last decades, Sichuan experienced a high speed economic development: from the view of GDP, from 2005 through 2010, the total GDP in Sichuan province are 738.5 billion yuan, 869.0 billion yuan, 1056.2 billion yuan, 1260.1 billion yuan, 1415.1 billion yuan and 17185.5 billion yuan, respectively (current price, see Table 1); from the view of GDP growth rate, from 2005 through 2010, the GDP growth rate in Sichuan province are 12.8%, 13.5%, 14.5%, 11.0%, 14.5% and 15.1% (constant price, see Table 1). Beyond this, per capita GDP in Sichuan province over the above period kept increasing from 8721 yuan to 26133 yuan, which increased almost by 3 times (see table 1).Additionally, the industrial structure was kept to optimize, the share of the first industry (the agricultural industry), the second industry (manufacturing industry) and the third industry (the service industry) in the whole GDP was adjusted from 20.1% : 41.5% : 38.4% to 14.1% : 52.4% : 33.4%.

On the other hand, with the development of economy, the urbanization rate kept increasing. The urbanization rate was increased from 23.30% in 2005 to 26.25％ in 2010 (see Table 2)

Table 1 Some Key Economic Indicators in Sichuan Province from 2005 to 2010

Year	GDP	GDP Growth Rate	Per Capita GDP	Industrial Structure
2005	738.5	12.8%	8721	20.1% : 41.5% : 38.4%
2006	869.0	13.5%	10613	18.4% : 43.4% : 38.2%
2007	1056.2	14.5％	12963	19.2% : 44.0% :3 6.8%
2008	1260.1	11.0％	15495	17.6% : 46.2% : 36.2
2009	1415.1	14.5％	17339	15.8% : 47.4% : 36.8%
2010	1718.5	15.1％	26133	14.1% : 52.4% : 33.4%

Source: China Statistical Yearbook (2011); Sichuan Statistical Yearbook (2010)

However, economy growth and population increase in Sichuan over the above years account for the decrease in arable land area for one reason, economy development is based on the acquisition of land, especially arable land; for the other reason, urbanization level improve means that population migration from rural region to urban region so that they need more space to live in. All above factors contribute to the arable land area decrease. The data from bureau of statistics in Sichuan province shows that the arable land area in Sichuan province experienced different change in different period: (1) from 1992 through 1999, there was a slow decrease in, the arable land area ,which only decreased from 461.19 ten thousand hm^2 to 445.47 ten thousand hm^2; (2) from 2000 through 2003, there was a sharp decrease in arable land area, which decreased from 434.61 ten thousand hm^2 to 390.37 ten thousand hm^2; (3) from 2004 through 2009, there was a slow increase in arable land area, which increased from 390.44 ten thousand to 396.71 ten thousand hm^2. In all, the arable land area had a tendency of reduce (see Table 3).

Table 2 Population and its Structure in Sichuan Province over the Period of 2005-2010 Unit: ten thousand people; %

Year	Total Population	Male	Female	Rural Population	Urban Population	Urban Level
2005	8642.1	4483.6	4158.5	6628.3	2013.8	23.30
2006	8722.5	4520.3	4202.2	6651.7	2070.8	23.74
2007	8815.2	4566.4	4248.8	6675.2	2140.0	24.28
2008	8907.8	4607.7	4300.1	6704.4	2203.4	24.74
2009	8984.7	4639.2	4345.5	6698.4	2286.3	25.45

Sichuan Statistical Yearbook (2010)

Table 3 The Arable Land Area Change and its Structure in Sichuan Province Unit: ten thousand hm^2

Year	Arable Land Area		Paddy Field Area		Dry Field Area	
	Total	Change	Total	Change	Total	Change
1992	461.19		235.44		225.75	
1993	459.38	-1.81	234.04	-1.4	225.34	-0.41
1994	457.96	-1.42	233.20	-0.84	224.76	-0.58
1995	456.04	-1.92	232.06	-1.14	223.98	-0.78
1996	454.31	-1.73	231.66	-0.4	222.65	-1.33
1997	451.99	-2.32	229.97	-1.69	222.02	-0.63
1998	449.49	-2.5	228.37	-1.6	221.12	-0.9
1999	445.47	-4.02	227.28	-1.09	218.19	-2.93
2000	434.61	-10.86	225.00	-2.28	209.61	-8.58
2001	428.44	-6.17	222.47	-2.53	205.97	-3.64
2002	405.99	-22.45	214.00	-8.47	191.99	-13.98
2003	390.37	-15.62	208.83	-5.17	181.54	-10.45
2004	390.44	0.07	207.86	-0.97	182.58	1.04
2005	390.60	0.16	208.07	0.21	182.54	-0.04
2006	391.66	1.06	207.94	-0.13	183.72	1.18
2007	394.59	2.93	208.58	0.64	186.01	2.29
2008	395.95	1.36	208.17	-0.41	187.79	1.78
2009	397.61	1.66	207.74	-0.43	189.87	2.08

Table 4 Arable Land Area Forecasting Result in Sichuan Province Unit: ten thousand hm^2

Year	2010	2011	2012	2013	2014
GM(1,1)	394.23	392.35	390.18	388.56	386.64
Regression Model	396.14	395.19	394.24	393.29	392.34
Difference	-1.91	-2.84	-4.06	-4.73	-5.70

4. RESULTS AND DISCUSSION

The above arable land area from 1992 to 2009 in Sichuan province is input the gray system prediction package, choose the GM (1, 1) module function and choose the forecasting years as the next five years in order to improve the accuracy of forecasting whose result of arable land area in the near future can be acquired listed as Table 4.

The forecasting result of arable land area from 2010 through 2104 shows that it still keep decreasing over the above years, the arable land area is going to reduce 7.59 ten thousand hm^2, which demonstrate that reduce averagely almost 1.52 ten thousand hm^2 each year.

In order to decide whether the GM (1, 1) model is suitable for forecasting the arable land area and to decide its accuracy, the regression model was introduced. The results are also listed as Table 4. Compared with the two results originated by different model, it obviously can see that there is a great gap between them and the accuracy of the GM (1, 1) model is higher than the regression model. Moreover, with time goes by, the gap become greater and greater from 1.91 ten thousand to 5.70 ten thousand. Apparently, the GM (1, 1) modest is more suitable for forecasting arable land area.

5. CONCLUSION AND POLICY IMPLICATION

To explore the arable land area change in Sichuan province in the next years so that the precautions could be taken in advance, this study introduces the GM (1, 1) model and makes use of the data from statistics to forecast the arable land area .the results shows that in the next five years, Sichuan province is still faced with the fact that the arable land area increase from 394.23 ten thousand hm^2 to 386.64 ten thousand hm^2. This study find further that GM (1, 1) model has higher accuracy than the other model, so it is more scientific to use this model to implement forecasting.

The policy implication is that although all level government carry out serious arable protection policy such as the arable land protection is the national fundamental policy, the land law in China provide all people have the duty to protect arable land, the arable land area keep decrease for the reason that the economic growth and urbanization level improvement. So, it is essential to take more reasonable and serious measure to protect arable land in case its sharp reduce in Sichuan province.

Firstly, the approach of arable land protection should be changed greatly from planning method to market method. Planning method is more a behavior of government; the farmers can’t benefit a lot from arable land protection. Under such circumstances, the farmers are not voluntary to do such things. But in China including Sichuan province, the farmer is main body of arable land protection. That means it is impossible to succeed in arable land protection without the farmer’s participation. Above all, the arable land protection approach should be adjusted from planning method to market method to improve the farmer’s enthusiasm for protection of arable land.

Secondly, the policy of urbanization should be improved to save arable land area. On one hand, the policy-maker should take different policy for different region. The large scale city, the medium scale city and the small scale city should be acquired the fair and equal development opportunity. The central government and the local government should be intentionally guide different scale city development by political, economical and legislative measurements.

Finally, the urban development should be more intensive. Different from European Union, America and other developed country in the world, China is behind in economic growth while it has much population and relative litter land resource. In view of this, china should use urban land more intensively. On one hand, urban sprawl should be avoid in china by multiply measurement; on the other hand, the government should encourage the developer develop the brown field in the city. Additionally, the structure urban land use should be adjusted according land rent. By those ways, some arable land should be saved.

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Author Introduction

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